

## Low Cost Antennas for Direct Broadcast Satellite Radio

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**Introduction:** The Direct Broadcast Satellite Radio (DBSR) Program is a joint effort between NASA and the United States Information Agency/Voice of America (USIA/VOA). DBSR will offer audio signals with various levels of sound quality (AM, FM, and CI) to reach a variety of radio receiver types (fixed, portable, and mobile) in various environments (indoor/outdoor, rural, urban, and suburban). JPL has successfully conducted two reception experiments and demonstrations via a NASA Tracking Data Relay Satellite (TDRS) at 62° West longitude with the sound signal sent from White Sands, New Mexico. These live demonstrations were conducted at Pasadena, California and at Buenos Aires, Argentina in June and September, respectively. This paper describes the low cost antennas developed at JPL for the two demonstrations. They are the drooping dipole and the  $TM_{21}$  mode circular patch antennas for mobile platforms as well as the medium gain antenna for indoor environments.

**Antenna Requirements:** The mobile antenna requirements are: (1) small size and mass, (2) 2.05 GHz operating frequency, (3) right hand circular polarization (RHCP), (4) 360° azimuthal coverage, (5) at least 4.5 dBic peak gain, and (6) optimum coverage between 40° and 48° from zenith. The mobile antennas are to be mounted on an 18" diameter ground plane simulating the automobile's antenna mounting platform. The medium gain antenna requirements are same as the mobile antenna except providing at least 12 dBic peak gain.

**Omni Drooping Dipoles:** Two drooping dipole antennas (S1 and S2) were designed based on the previous MSAT's (Mobile Satellite) antennas at L-band [1]. Figure 1 illustrates the physical configuration of this antenna. The impedance match tuning ring, dipole length (1.2" short arms' length and 1.8" long arms' length) and height (3.2") were found to achieve optimum RF performance at 2.05 GHz. The height of the dipole arms were first adjusted for a beam peak at 43°. However, the highest peak gain was 2 dBic, which is too low to be accepted. The reason why we get such a low gain value is that the energy tends to radiate toward the zenith direction instead of concentrating in the 43° direction. Thus the height was increased further to reduce the energy radiated in the zenith direction. However, the beam peak emerges at ±60°. Figure 2 shows a representative measured radiation pattern for one of these drooping dipole antennas.

**Omni Patch Antennas:** The circular patch antenna, as illustrated in Figure 3, is modified from the MSAT  $TM_{21}$  mode patch antenna [2]. The patch antenna's diameter is 6" with a 5.2" diameter top radiating patch, which is printed on a 0.5" thick Nomex honeycomb with 5 mil thick Micaply face sheets. The original MSAT patch antenna was measured with an external feed component consisting of a two-way power divider and two 90° hybrids. To reduce the feed circuit loss and to provide a precise amplitude and phase input at the four feed ports, a printed circuit board (PCB) feed, as depicted in Figure 4, was designed and fabricated. Thus the patch antenna was measured either with a PCB feed or an external feed. Indeed, the patch antenna with the PCB feed has approximately one dB higher gain and is much more conformal than the patch antenna with an external feed component. Table 1 summarizes the measured peak gain, the peak direction, and the VSWR of all the antennas. Figure 5 shows a representative measured radiation pattern for one of these patch antennas. Another patch antenna with a thin substrate (0.125" thick Teflon-Fiberglass) and a smaller

size (3.75" diameter patch) may be considered for further reducing the size of this  $TM_{21}$  mode patch antenna.

**Medium Gain Antennas:** Two patch array antennas (8.5" by 8.5" in size and 0.126" thickness) were developed to provide at least 12 dBic peak gain (at broadside). One array uses a conventional feed and the other array uses the sequentially arranged feed technique [3,4], as illustrated in Figure 6, to generate circular polarization. The sequentially fed array gives better 2:1 VSWR bandwidth (132 MHz BW), axial ratio (0.8 dB AR), and sidelobe level (-24 dB S1L) performance than the conventional feed array (82 MHz BW, 1.4 dB AR and -13 dB S1L). Note that the antenna size may be further reduced to approximately 6" by 6" in size by replacing the feed lines with a PCB feed circuit board behind the radiating patch elements.

**Conclusion:** Two different low gain omni antennas (the drooping dipole and the  $TM_{21}$  mode circular patch antennas), and two medium gain patch antennas were developed for the successful demonstrations in Pasadena, California and Buenos Aires, Argentina. These low cost antennas can be used indoor or outdoor to receive digital audio signals from the TDRS satellite. The patch antennas are more conformal than the drooping dipole antennas.

#### References:

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**TABLE 1. Measured Antenna Performances Summary at 2.05 GHz**

Antenna Type	VSWR	Beam Peak (degree)	Axial Ratio (dB)	Gain (dBic)
Drooping Dipole S1	1.12	60	0.6	4.8
Drooping Dipole S2	1.22	60	1.0	4.7
Patch w/o PCB Feed	1.4	36	2.0	5.5
Patch with PCB Feed	1.56	36	2.0	6.5
Conventional Array	1.13	0	1.4	13.7
Sequential Array	1.48	0	0.8	12.0

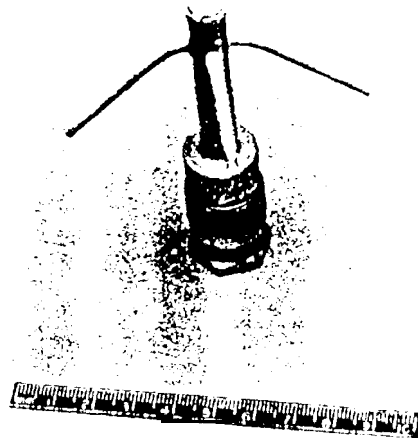


Figure 1. Crossed Drooping Dipole

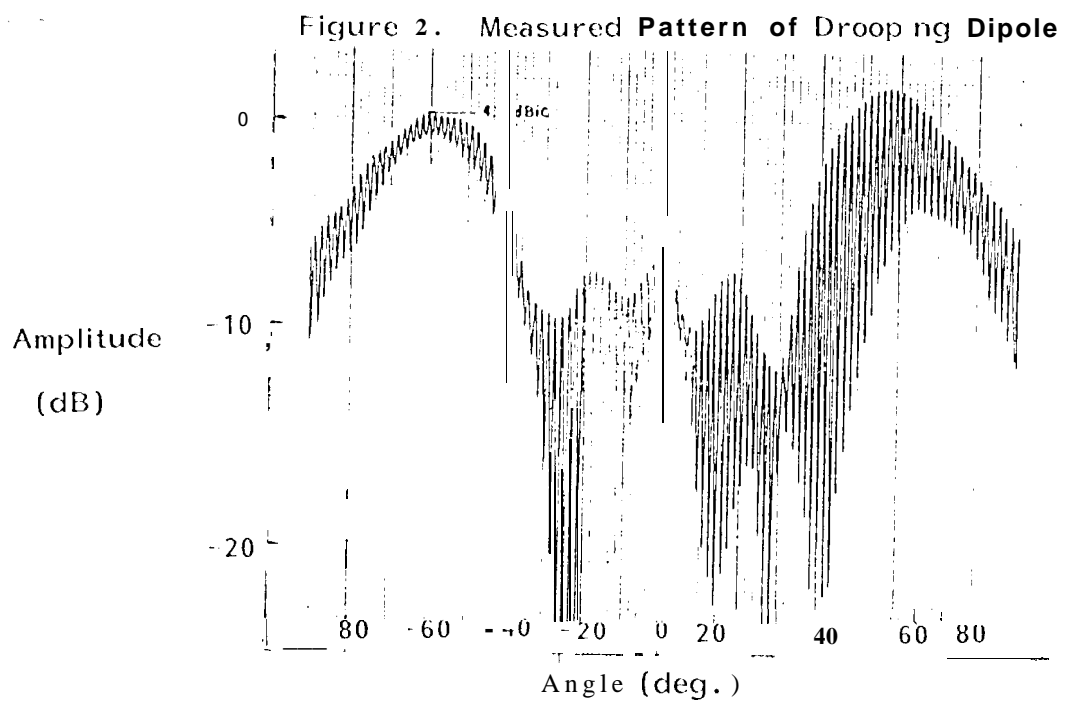


Figure 3.  $1M_{21}$  Mode Circular Patch Antenna

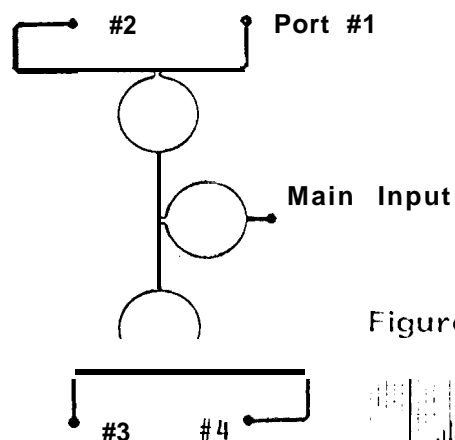


Figure 4. Printed Circuit Board Feed for the  $TM_{21}$  Mode Patch Antenna.

Figure 5. Measured Pattern of the  $TM_{21}$  Mode Patch Antenna

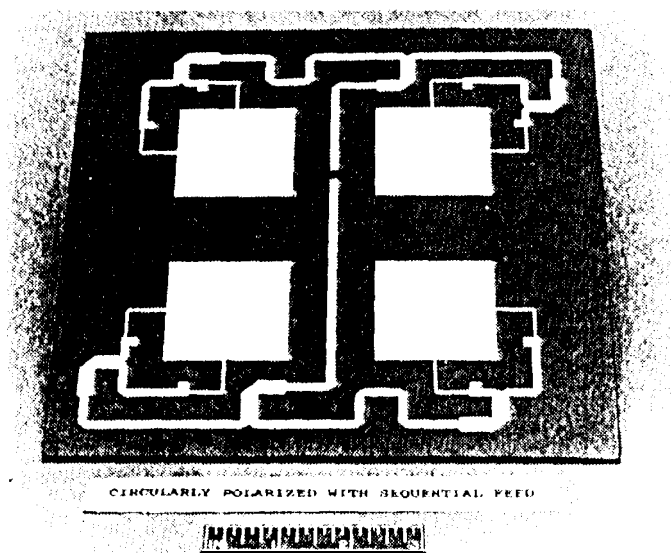
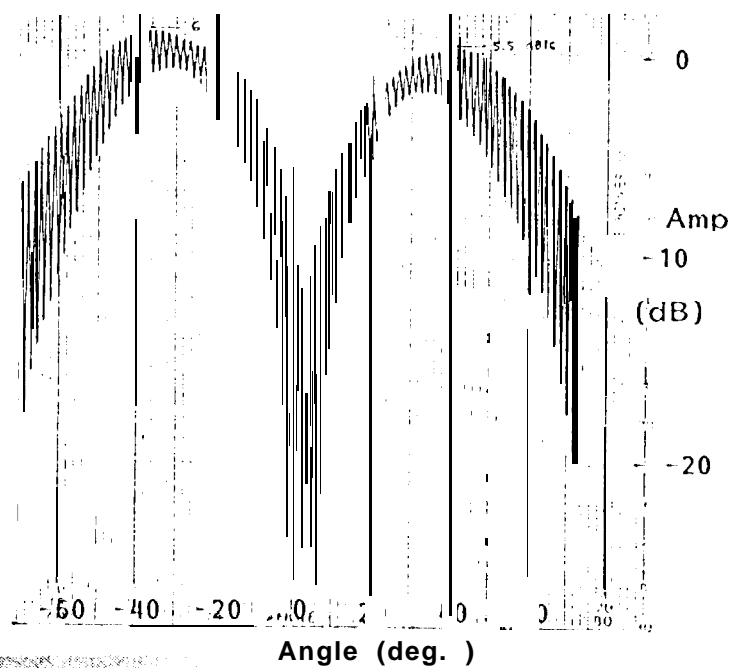


Figure 6. Medium Gain Patch Array Antenna with Sequential Feed.